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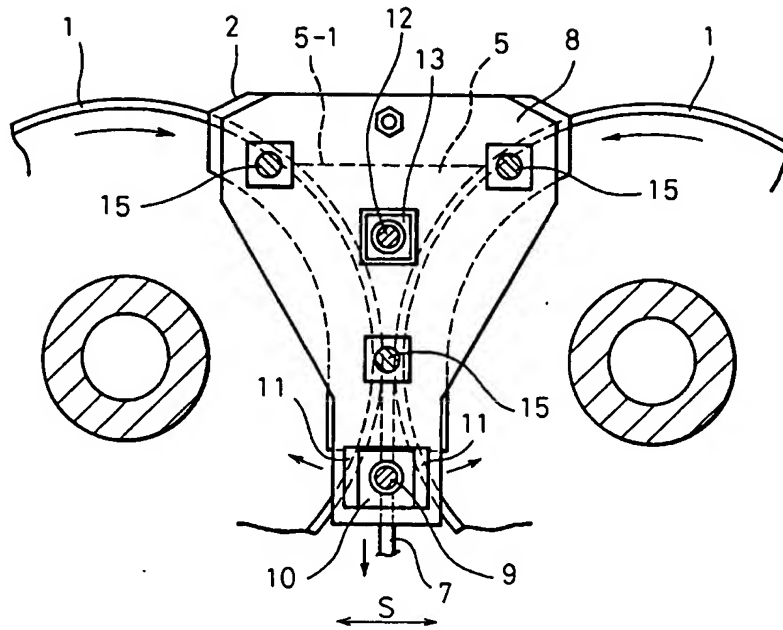
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(54) METHOD OF CONTINUOUSLY CASTING METAL THIN STRIP.

(57) A method comprising the steps of forming a pouring basin for molten metal between a pair of rotary cooling drums the axes of which are parallel with each other and a pair of side gates which are in contact with the end faces of the pair of rotary cooling drums, and pouring the molten metal into the basin for continuously casting thin cast pieces, the method being characterized in that casting is effected while vibrations at a frequency f obtained from the following equation are imparted to the side gates in the horizontal direction in which the centers of the axes of the drums are connected to each other: $aA + b + cV \leq f \leq 50$, where A: an amplitude (mm) of the side gates at the kissing point portion of the cooling drums, in the range of 0.5 mm to 5 mm; V: a casting speed (m/min) that is predetermined in accordance with a desired thickness of cast plate; and a, b, c: constants.

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Fig. 6



[Technical Field]

The present invention relates to a process for producing a thin metallic strip by continuous casting in a twin drum system and particularly to a method of vibrating a side gate constituting a pouring basin portion.

[Background Art]

A conventional continuous casting process using a twin drum system comprises forming a pouring basin portion for a molten metal comprising a pair of rotary cooling drums respectively having shafts parallel to each other and a pair of side gates respectively in contact with the end face of the cooling drums, solidifying the molten metal poured into the pouring basin at a stage leading to the kissing point while cooling the molten metal by means of the cooling drums, thereby forming a thin cast strip, and pulling the cast strip downward.

In casting a thin strip by the above-described process, a gap often occurs between the end face of the cooling drum and the side gate in press contact with the end face of the cooling drum. In this case, the molten metal enters the gap, or solidified matter adheres to the surface of the side gates and grows, so that it frequently becomes difficult to conduct casting due to the breaking of a solidified shell or entrainment on the cooling drum attributable to the formation of casting fins.

In order to solve this problem, Japanese Unexamined Patent Publication (Kokai) No. 60-166146 discloses a method of vibrating the side gates in the horizontal direction.

Since, however, the object of the technique disclosed in the above-described document is to remove solidified matter solidified and grown on the surface of the side gates, the proper range of reciprocating movement of the side gates in the horizontal direction is as follows.

1 cycle: 0.25 to 5.0 sec

degree of movement in each direction, from rest position: 5 to 20 mm

Specifically, the amplitude of the said gate vibration is in the range of from 10 to 40 mm, and the number of vibrations per sec (frequency) is in the range of from 5 to 0.2 Hz. That is, the above-described technique is characterized in that the vibration is conducted slowly but with a large amplitude.

The present inventors have conducted various studies on the above-described technique and, as a result, have found that although such means is effective in preventing the formation of casting fin, a delay of solidification of the molten metal occurs at the end portion of the cooling drum to form a porosity and a large secondary casting fin.

Specifically, when the amplitude of the side gate becomes large, a shell which is growing on the cooling surface of the drum is unfavorably floated from the cooling drum by shearing stress, which delays the development of the shell, so that there occurs a delay in solidification.

An object of the present invention is to remove solidified matter formed on the side gates and to prevent the delay of solidification at the end portion of the cooling drum.

[Construction of the Invention]

In order to attain the above-described object, the present invention has the following constitution. Specifically, the present invention is directed to a process for producing a thin metallic strip by continuous casting, comprising forming a pouring basin portion for a molten metal between a pair of rotary cooling drums respectively having shafts parallel to each other and a pair of side gates in contact with the end face of said cooling drums and pouring said molten metal into said pouring basin portion for a molten metal to continuously cast a thin strip, characterized in that a side gate frequency, f (Hz), is determined according to the following formula (1) using the initial value (in the range of from 0.5 to 5 mm) of a side gate amplitude, A , at a kissing point of said pouring basin portion for a molten metal and the casting rate, V (m/min), previously determined from a target sheet thickness of a cast strip and casting is conducted while vibrating said side gates at the determined frequency, f , at an amplitude, A :

$$aA + b + cV \leq f \leq 50 \quad (1)$$

The range of the side gate amplitude, A , is determined so that the occurrence of casting fin and the delay of solidification can be avoided. The casting rate, V , is limited, as one of the casting conditions, to a particular range for each apparatus and is continuously measured by means of a casting rate detector provided on, for example, a shaft of the drum, and when the casting rate is varied, at least one of the amplitude and the frequency of the side gate vibration is adjusted according to the formula (1).

In the above-described formula (1), a, b and c are each a constant.

[Brief Description of Drawings]

- 5 Fig. 1 is a diagram showing the relationship between the amplitude of side gate vibration, the frequency of side gate vibration and the delay of solidification when the casting rate is 40 m/min;
 Fig. 2 is a diagram showing the relationship between the amplitude of side gate vibration, the frequency of side gate vibration and the delay of solidification when the casting rate is 80 m/min;
 Fig. 3 is a diagram showing the relationship between the amplitude of side gate vibration, the frequency
 10 of side gate vibration and the delay of solidification when the casting rate is 120 m/min;
 Fig. 4 is a perspective diagram showing the state of practice of the present invention;
 Fig. 5 is a partly broken side view of the principal portion of a vibrating device for side gates;
 Fig. 6 is a cross-sectional view taken on line I-I of Fig. 5;

15 [Best Mode for Carrying Out the Invention]

The best mode for carrying out the invention will now be described in detail.

At the outset, an embodiment of the present invention will be described with reference to Fig. 4. In the present invention, use is made of a casting apparatus shown in Fig. 4, that is, a casting apparatus wherein
 20 cooling drums 1, 1 provided with a cooling mechanism in the inside thereof are provided in such a manner that the shafts are parallel to each other and a pair of side gates 2, 2 are provided in contact with the end face of said cooling drums 1, 1, thereby forming a pouring basin portion 4. A molten steel 5 is poured into the pouring basin portion 4 through a molten metal pouring nozzle 3, and the cooling drums 1, 1 are rotated in the direction of arrows a, a to cool and solidify the molten metal 5. The solidified layer is subjected to
 25 press contact at the kissing point 6 to form a thin cast strip 7.

In the above-described apparatus, a laboratory apparatus used to obtain an effect of the present invention is shown in Figs. 5 and 6. In the drawings, side gate 2 is pressed against a pair of cooling drums 1 by means of a pressing device 15 through a vibrating plate 8 to form a pouring basin portion. The cooling drums 1 are rotated while conducting slide contact with a refractory material 2-1 provided on the surface of
 30 the side gate 2. On the back face of the vibrating plate 8 for fixing the side gate 2, a bearing 3 is provided below the molten metal surface 5-1 and above the kissing point 6 of the cooling drum, preferably around the center of gravity of the side gate or the center of gravity of a surface in contact with the molten metal of the side gate, and the tip of a vibration supporting shaft 12 fixed to a frame 14 is inserted and rotatably mounted in the bearing 13. On the other hand, a guide 11 is provided below the kissing point 6 of the
 35 cooling drum, and a slider 10 is slidably fit into the guide 11. The eccentric tip of an excitation shaft 9 which is removably and rotatably supported on the frame 14 is supported on the slider 10 so that it can be rotated by the shaft. In this state, when the excitation shaft 9 is rotated by means of a drive (not shown), the slider 10 reciprocates by sliding within the guide 11. This causes the vibrating plate 8 to be moved about the vibration supporting shaft 12, thereby vibrating the side gate 2 fixed to the vibrating plate 8. Thus, vibration
 40 is imparted to the side gate 2 in a direction horizontal to an imaginary line formed by connecting the shaft centers of the cooling drums to each other.

The present inventors have produced a thin strip by using the above laboratory apparatus shown in Fig. 5 according to a process which comprises pouring a molten SUS304 austenite-based stainless steel into the pouring basin portion and subjecting the molten steel to continuous casting at a casting rate, V, of 40 m/min
 45 to produce a thin strip. In this case, the amplitude, A (mm), and the frequency, f (Hz), were varied to evaluate the delay of solidification at the end portion of a cast strip. The results are shown in Fig. 1. The delay of solidification was expressed in terms of the length of delay of solidification in the direction of a cast strip at the end portion of the cooling drum.

As shown in the drawing, when the side gate amplitude, A, is less than 0.5 mm, it becomes difficult to
 50 peel off the solidified matter formed on the wall surface of the fixed gate, so that the occurrence of casting fin became significant. On the other hand, when the side gate amplitude exceeds 5 mm, a shear stress occurs between the cooling drum and the shell formed through the contact of the molten metal with the cooling drum, so that the shell is pulled from the cooling drum by the shear stress. This causes a delay in solidification and in turn the occurrence of porosity and a large secondary casting fin. On the other hand,
 55 when the side gate frequency, f, is less than a value determined by the following equation

$$f = a \times A + b + c \times V = 2 \times A + 5 + 0.1 \times 40 \\ = 2A + 9 \text{ (Hz)}$$

5 wherein $a = 2$, $b = 5$ and $c = 0.1$,

it becomes difficult to peel off solidified matter formed on the wall surface of fixed gates, so that the occurrence of casting fin becomes significant, which causes the delay of solidification to become significant. When the side gate frequency, f , exceeds 50 Hz, there occurs breaking of side gate refractories which is causes operation failure.

10 Thus, it was found that in the above-described case, good results can be obtained by vibrating the side gates at an amplitude, A , in the range of from 0.5 to 5 mm and a frequency, f , in the range of from $(2A + 9)$ to 50 Hz. This frequency range suggests that when an increase in the amplitude, A , is intended, it is necessary to increase the frequency for the purpose of preventing peeling of the shell.

15 Then, a steel of the same type as that used above was cast at a casting rate, V , of 80 m/min. As shown in Fig. 2, the lower limit of the side gate frequencies corresponding to each side gate amplitudes was increased, so that the proper range became narrow. When the casting rate, V , was 120 m/min, as shown in Fig. 3, the lower limit of the side gate frequency was increased. Thus, when the casting rate, V , is increased, if the frequency is around the lower limit value, the frequency should be increased to a suitable frequency.

20 Specifically, the present invention is characterized in that the frequency of the side gate vibration, and the amplitude, at the kissing point portion are properly selected according to the casting rate. The vibration of the side gate under such a condition shortens the delay in solidification in the direction of width at the end portion of the cooling drum, which reduces the amount of trimming at the time of cold rolling, which contributes to a remarkable improvement in production yield.

25 The casting rate, V , is previously determined for each casting machine by determining the thickness of a sheet to be cast according to the following equation.

$$B = K\sqrt{t} \quad (2)$$

30 When the arc angle and the drum diameter are 40° and 1200 mm, respectively,

$$B = K\sqrt{1.2/9V} \quad (3)$$

$$V = 1.2 K^2/9B^2 \quad (4)$$

35 wherein K represents the coefficient of solidification, t represents the contact time and B represents a specified sheet thickness. The V value can be determined because K is a value inherent in the casting machine and B is known before casting.

40 Therefore, the side gate amplitude and the initial value of the frequency are determined based on the casting rate, V .

Although the present invention has been described based on SUS304 austenite stainless steel, it was confirmed through various tests that the vibration of the side gates according to the above-described equation and the above-described numerical values is very effective in suppressing the occurrence of casting fin and preventing the delay of solidification when the steel is an austenite stainless steel. Further, in 45 other types of steel as well, the application of vibration to the side gates in substantially the same manner as that described above is effective.

[Examples]

50 Steels listed in Table 1 were cast at three casting rates, that is, 40 m/min, 80 m/min and 120 m/min into thin cast strips having thicknesses given in Table 2. The side gate vibration conditions, yields, etc. in this case are given in Table 2.

In Comparative Examples Nos. 2 and 5, the frequency relative to the amplitude was low and outside the scope of the present invention, so that the delay of the solidification was large and the yield was reduced 55 due to an increase in the degree of trimming.

Regarding the steels used, A represents a SUS304 austenite-based stainless steel, B represents a low-carbon Al killed steel, C represents a silicon steel sheet, and D represents a ferrite-based stainless steel.

Table 1

No.	C	Si	Mn	P	S	Ni	Cr	Al	O	N	Nb
A	0.045	0.45	1.01	0.030	0.005	8.30	18.20	0.002	0.0058	0.0325	0.020
B	0.035	0.05	0.20	0.003	0.001	0.01	0.005	0.030	0.0025	0.0034	0.003
C	0.005	3.15	0.005	0.003	0.003	0.02	0.09	0.04	0.0011	0.0020	0.001
C	0.060	0.30	0.21	0.019	0.001	0.12	16.50	0.034	0.0034	0.0175	0.002

Table 2

No.	Casting rate, m/min	Sheet thickness, mm	Side gate conditions		Length of delay of solidification, mm	Degree of trimming on one side, mm	Yield, %	Classification	Steel used
			amplitude, mm	frequency, Hz					
1	40	3.8	1	10	0.8	0	100	Ex.	A
2	40	3.8	1	5	30.0	35	91	Comp. Ex.	A
3	40	3.8	0.5	20	1.0	0	100	Ex.	A
4	40	3.8	5	20	1.5	0	100	do.	A
5	40	3.8	3	10	25.0	20	95	Comp. Ex.	A
6	80	2.3	3	15	5.0	7	98	Ex.	A
7	80	2.3	3	50	0.5	0	100	do.	A
8	120	1.8	3	50	1.0	0	100	do.	A
9	40	3.5	1	15	3.4	5	98	do.	B
10	80	2.2	3	50	1.6	4	98	do.	B
11	40	3.6	1	15	2.4	4	98	do.	C
12	80	2.4	3	50	1.8	3	99	do.	C
13	40	3.8	1	15	1.7	3	99	do.	D
14	80	2.3	3	50	0.5	0	100	do.	D

[Industrial Applicability]

As described above, according to the present invention, since no delay of solidification at the end portion of the cast strip occurs, it is unnecessary to conduct trimming, which contributes to a remarkable

improvement in the yield, so that the effect of the present invention, on the production of a cast strips of stainless steels and other steels is very large.

List of Reference Numerals of the Drawings

5	1	....cooling drum,
	2	....side gate,
	3	....molten metal pouring nozzle,
	4	....pouring basin portion,
10	6	....kissing point portion,
	7	....thin cast strip,
	8, 16	....vibrating plate,
	9, 19	....excitation shaft,
	10, 20	....slider,
15	11, 21	....guide,
	12, 17	...vibration supporting shaft,
	13, 18	....bearing,
	14	....frame,
20	15	....pressing device,

Claims

1. A process for producing a thin metallic strip by continuous casting, comprising forming a pouring basin portion for a molten metal between a pair of rotary cooling drums respectively having shafts parallel to each other and a pair of side gates in contact with the end faces of said cooling drums and pouring said molten metal into said pouring basin portion for a molten metal to continuously cast a thin cast strip characterized in that said casting is conducted while vibrating said side gates at a frequency, f (Hz), determined according to the following formula in a direction substantially horizontal to an imaginary line formed by connecting the shaft centers of said cooling drums to each other:

$$aA + b + cv \leq f \leq 50 \quad (1)$$

wherein

- | | | |
|----|------------|--|
| 35 | A | represents the amplitude (mm) of the side gate at the kissing point portion of the cooling drum and is in the range of from 0.5 to 5 mm; |
| | V | represents the casting rate (m/min) previously determined from a desired casting sheet thickness; and |
| | a, b and c | are each a constant. |

2. The process according to claim 1, wherein the casting rate is detected during casting and, if necessary, at least one of the frequency, f , and the amplitude, A , is adjusted according to the formula (1).
3. The process according to claim 1, wherein said side gates are vibrated around a vibration supporting shaft provided below the molten metal surface of the pouring basin portion and above the kissing point portion of said cooling drums by means of an excitation means provided below said kissing point portion.
4. The process according to claim 1, wherein said side gates are vibrated around a vibration supporting shaft provided below the kissing point portion by means of an excitation means provided below the molten metal surface of the pouring basin portion and above the kissing point portion of said cooling drums.
5. The process according to claim 1, wherein said side gates are vibrated by reciprocating an excitation shaft provided substantially along the center line of the cast strip in a direction horizontal to an imaginary line formed by connecting the shaft centers of said cooling drums to each other.

Amended claims

1. A process for producing a thin metallic strip by continuous casting, comprising forming a pouring basin portion for a molten metal between a pair of rotary cooling drums respectively having shafts parallel to each other and a pair of side gates in contact with the end faces of said cooling drums and pouring said molten metal into said pouring basin portion for a molten metal to continuously cast a thin cast strip characterized in that said casting is conducted while vibrating said side gates at a frequency, f (Hz), determined according to the following formula in a direction substantially horizontal to an imaginary line formed by connecting the shaft centers of said cooling drums to each other:

$$aA + b + cV \leq f \leq 50 \quad (1)$$

wherein

- A represents the amplitude (mm) of the side gate at the kissing point portion of the cooling drum and is in the range of from 0.5 to 5 mm;
V represents the casting rate (m/min) previously determined from a desired casting sheet thickness; and
a, b and c are each a constant.

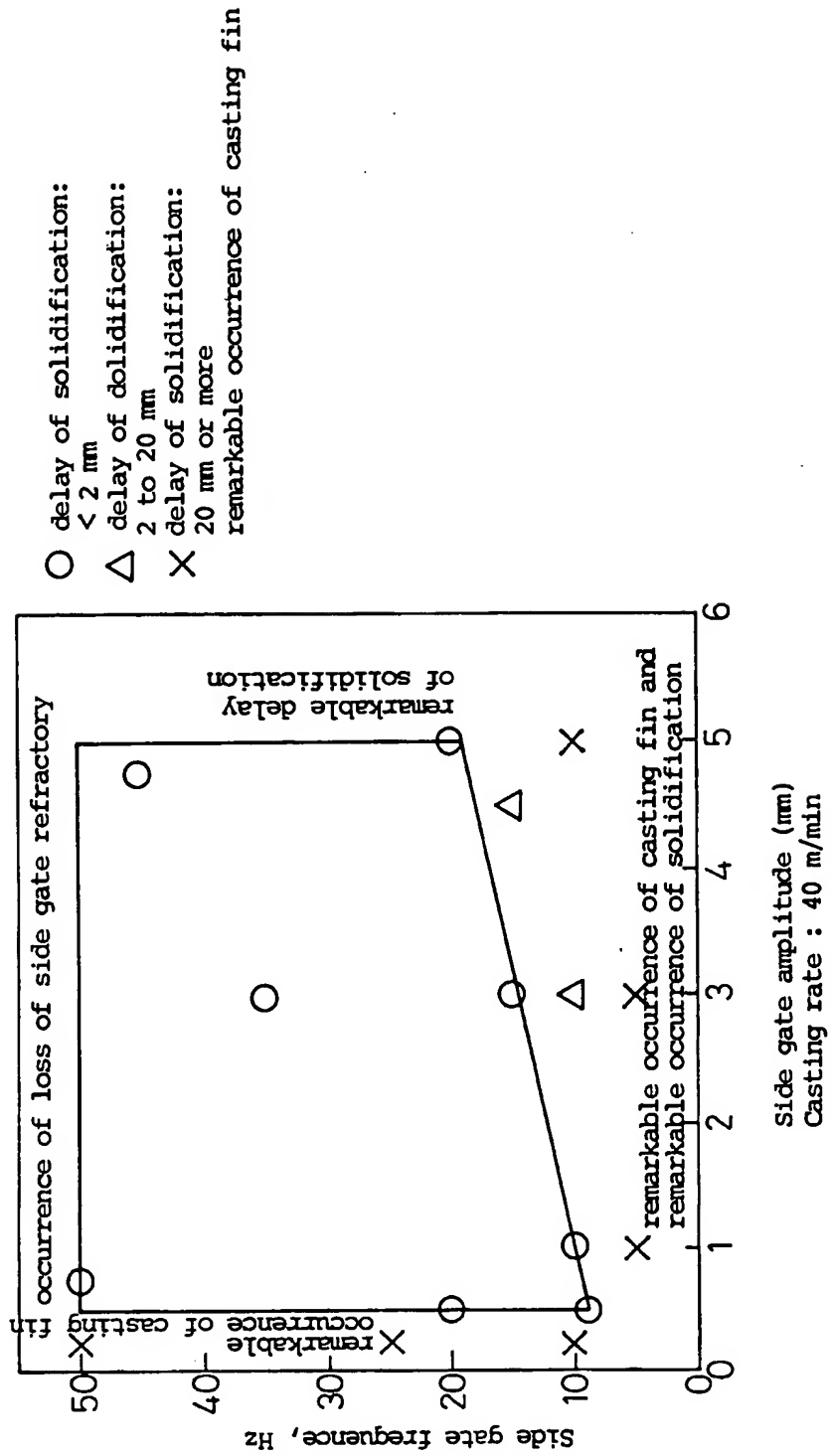
2. The process according to claim 1, wherein the casting rate is detected during casting and, if necessary, at least one of the frequency, f , and the amplitude, A , is adjusted according to the formula (1).

3. (delete)

4. (delete)

5. (delete)

Fig. 1



occurrence of loss of side gate refractory

ۛۛۛ

○ delay of solidification:
< 2 mm
△ delay of solidification:
2 to 20 mm
× delay of solidification:
20 mm or more
remarkable occurrence of

Δ delay of dolidification:
2 to 20 mm

X delay of solidification:
20 mm or more

remarkable occurrence of casting fin

remarkable delay
of solidification

X remarkable occurrence of casting fin and
remarkable occurrence of solidification

Side gate amplitude (mm)
Casting rate : 40 m/min

Fig. 2

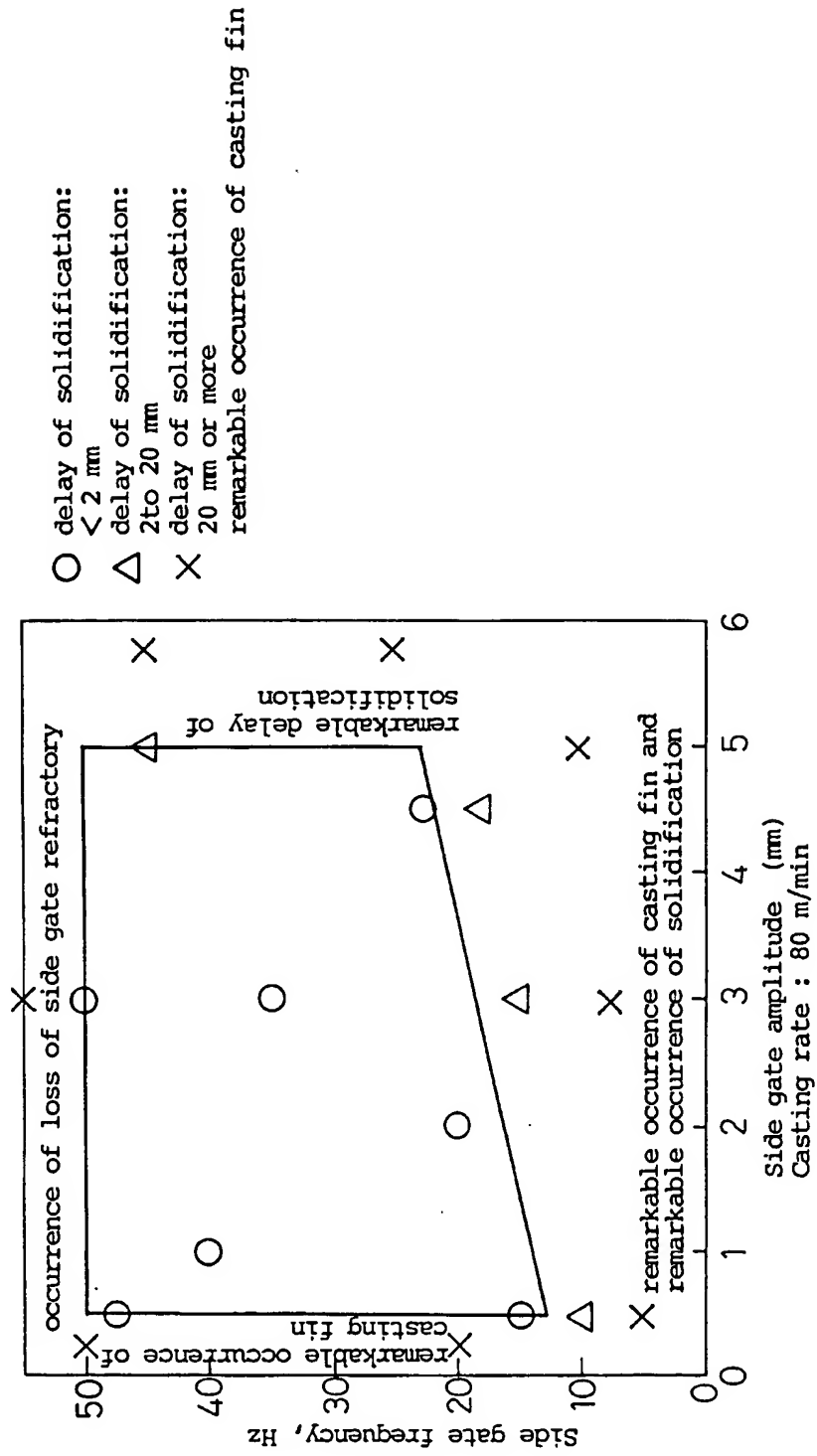


Fig. 3

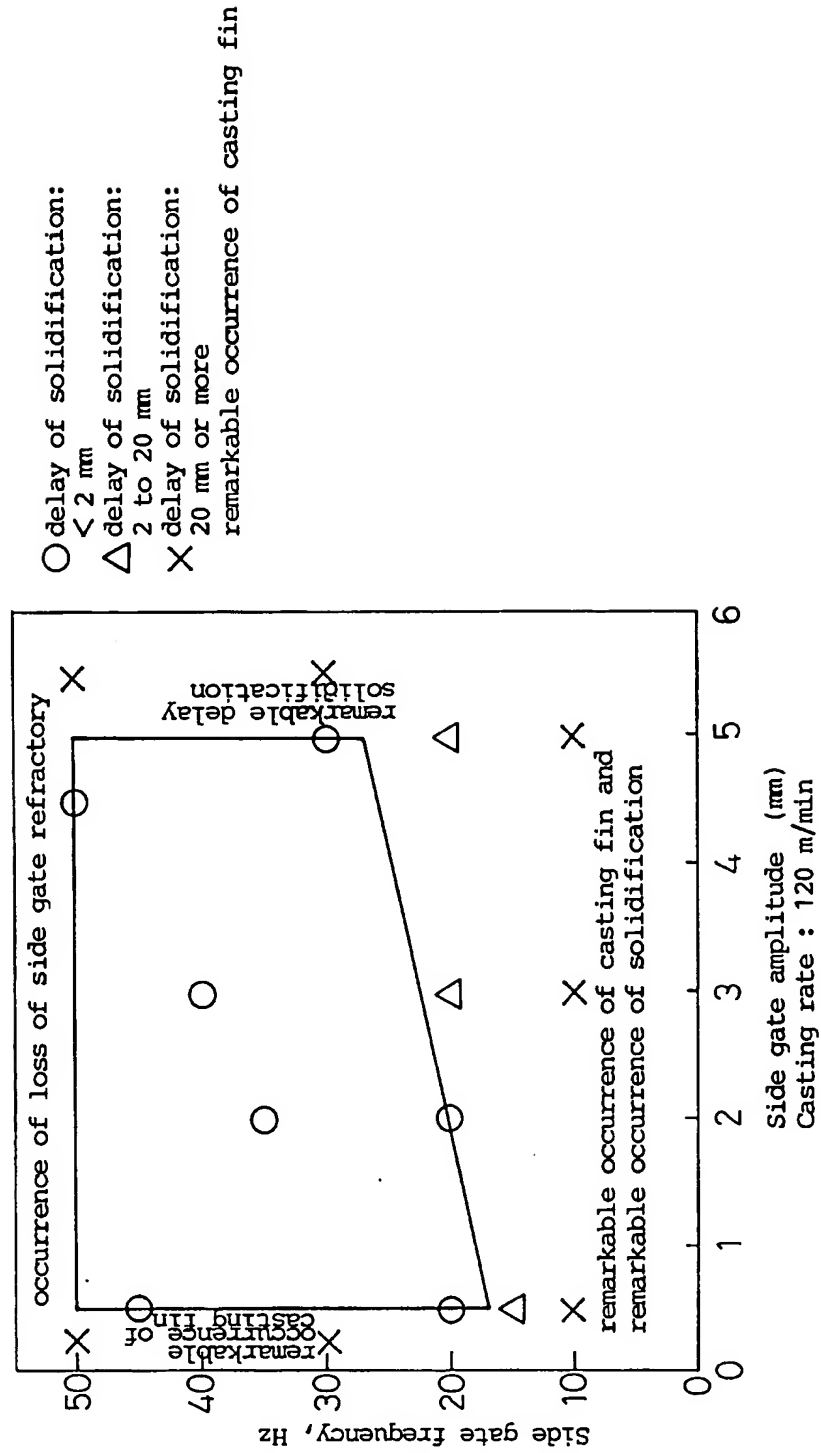


Fig. 4

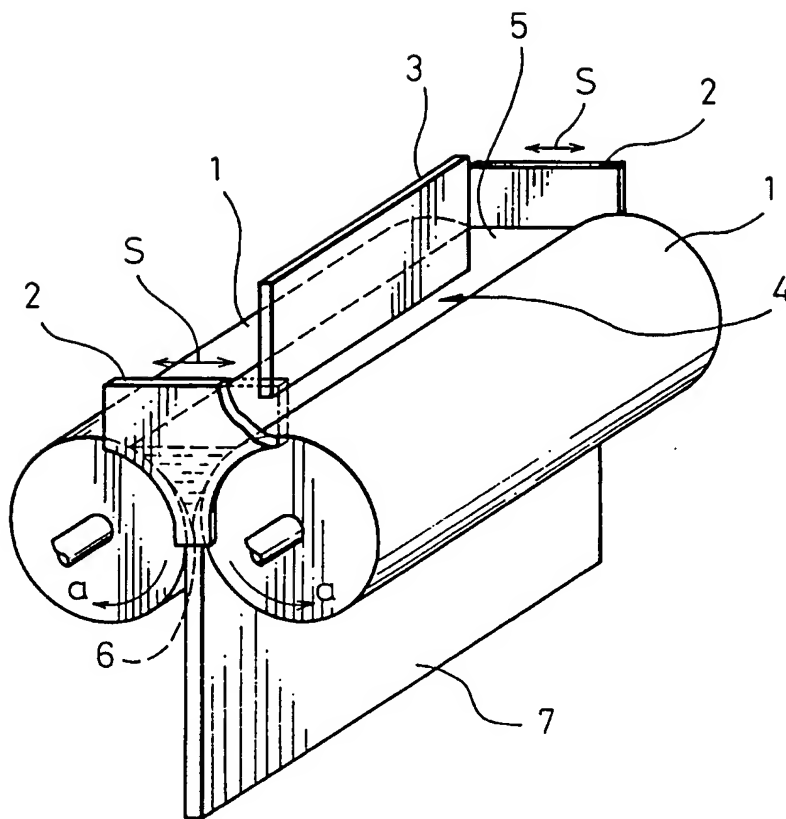


Fig. 5

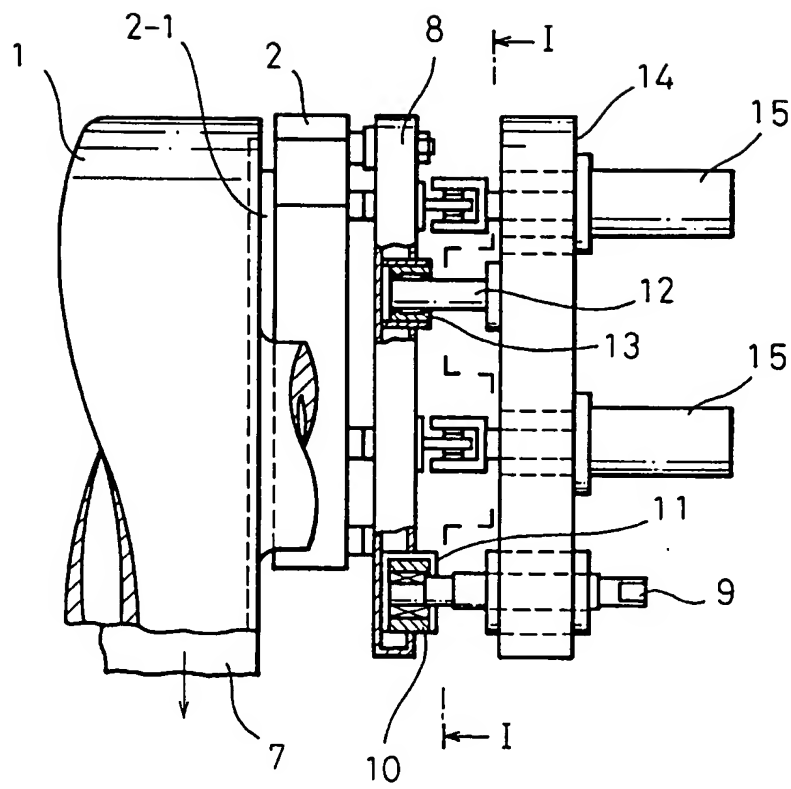
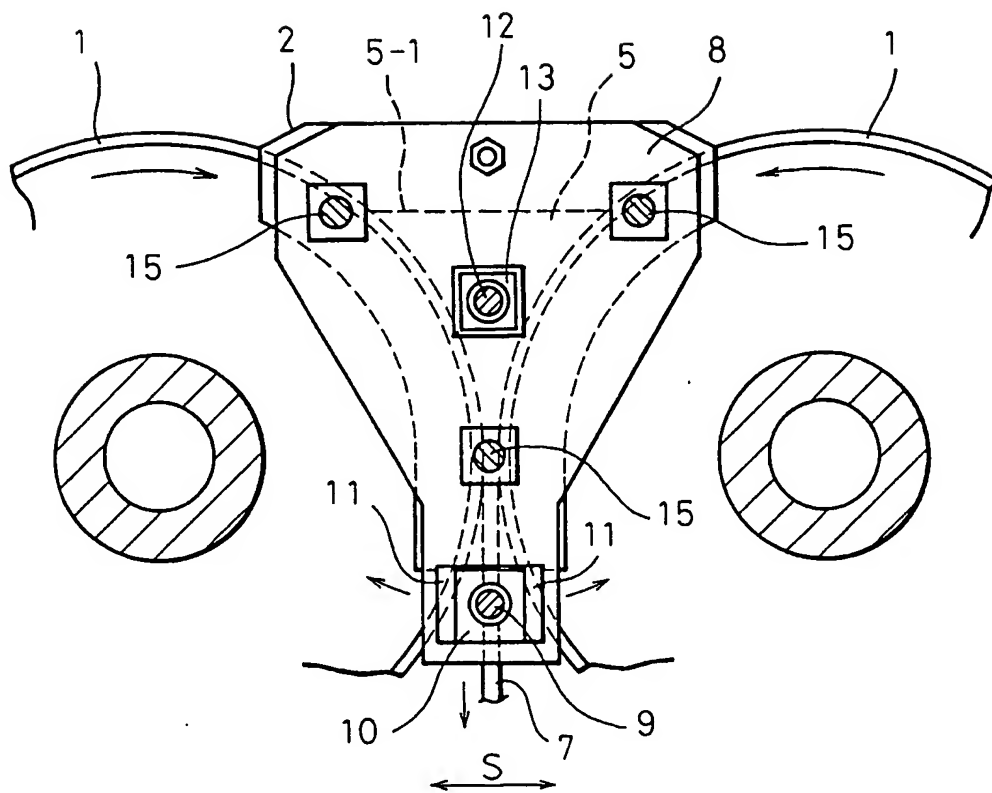


Fig. 6



INTERNATIONAL SEARCH REPORT

International Application No PCT/JP92/00316

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl ⁵ B22D11/06		
II. FIELDS SEARCHED		
Minimum Documentation Searched *		
Classification System	Classification Symbols	
IPC	B22D11/06	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched *		
Jitsuyo Shinan Koho	1926 - 1992	
Kokai Jitsuyo Shinan Koho	1971 - 1992	
III. DOCUMENTS CONSIDERED TO BE RELEVANT *		
Category *	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	JP, A, 64-40148 (Kawasaki Steel Corp.), February 10, 1989 (10. 02. 89), Line 6, upper part, left column to line 2, upper part, right column, page 4 (Family: none)	1
P	JP, A, 3-174954 (Mitsubishi Heavy Industries, Ltd.), July 30, 1991 (30. 07. 91), Lines 7 to 19, lower part, right column, page 2, Fig. 1 (Family: none)	4
Y	JP, A, 62-16853 (Hitachi Zosen Corp.), January 26, 1987 (26. 01. 87), Line 9, lower part, right column, page 3 to line 15, upper part, left column, page 4 & DE, A, 3616055 & US, A, 4694885	1, 2
<p>* Special categories of cited documents: ¹⁰</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"A" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
May 28, 1992 (28. 05. 92)	June 16, 1992 (16. 06. 92)	
International Searching Authority	Signature of Authorized Officer	
Japanese Patent Office		